Patent Application for

Joanna Margaret Williams

and

Darin Scot Williams

for

TITLE: AUTONOMOUS EAR-PLUG ALARM WITH SEPARATE SETTING DEVICE

CROSS-REFERNCE TO RELATED APPLICATIONS

This application claims the benefit of provisional patent application #60/251,372 filed 12/05/2000.

STATEMENT REGARDING FEDERALLY FUNDED R&D

No federal R&D funds were used in the development of this invention.

REFERENCE TO LIST OR CD APPENDIX

Not applicable.

BACKGROUND OF THE INVENTION-- FIELD OF INVENTION

This invention relates to timing devices, specifically to alarm clocks.

BACKGROUND OF THE INVENTION -- DESCRIPTION OF PRIOR ART

The need for help to awaken from sleep is so prevalent as to have spawned a vast variety of solutions over the centuries. When people share a room the problem becomes even more complex: sleepers often wish to wake without waking their roommates (to avoid the consequent wrath). If the sleeper happens to be

particularly hard of hearing, he risks not awakening at all, or waking others in nearby rooms. We wish to reliably awaken one sleeper without disturbing others.

Existing solutions range from the nearly adequate to the silly. They include pillow vibrators, vibrating wrist bands, audio alarms placed in or under the user's pillow, and even alarms that sit in the user's ear. But, all existing solutions have significant limitations.

U.S. patent 5,072,429 to Mair (1991) tries to deal with the problem by placing the alarm sound closer to the sleeper, so that it doesn't have to be loud enough to wake anyone else. Specifically, Mair places the alarm within a special pillow. Another common solution is a small speaker placed under the pillow, attached to the earphone jack of a conventional clock-radio. But such arrangements are relatively useless for waking a heavy sleeper without waking light sleepers in the same room. Light sleepers are often far more sensitive to sounds, so that a small difference in proximity is not enough to shield them. Even without this limitation, a restless sleeper is likely to remain asleep after moving off their pillow or shoving the device aside. U.S. patent 2,517,368 to Wiseley (1950) carries this idea to the limit by using a hearing-aid speaker. But in both concepts there is a significant safety hazard. Both require wires in which the sleeper can become entangled during sleep.

Pager type watches, such as U.S. patent 5,297,118 to Sakumoto (1994), could be used for a similar function. But again, there is the problem of making it loud enough to reliably wake the sleeper without waking anyone else. Particularly if the sleeper's arm wanders under the covers, this is a serious limitation. Anything loud enough to wake the sleeper in this circumstance will certainly wake their roommates when the alarm is above the covers. Also, this approach is still dependent upon an external timing source.

U.S. patents 4,093,944 to Muncheryan (1978) and 5,144,600 to Cheng (1992) avoid the sound volume problem by placing vibrating devices under the sleeper's pillow. Of necessity, the devices are relative large and inconvenient. U.S.

patent 4,920,525 to Meister (1990) expands this idea to a more general purpose timer and battery-powered vibrator, but with similar limitations. Vibrating devices that are not physically attached to the sleeper are relatively useless for the restless: they are too easily pushed aside during sleep.

U.S. patents 5,764,594 to Berman (1998) and 5,686,882 to Giani (1997) overcome this difficulty by using a vibrating wrist band. The vibration is triggered by a signal from a separate base station which actually does the timing. The operation of the wrist band is completely dependent upon the base station. It cannot be separate from it by more than a short distance (based on the signal range). A power failure in the base station prevents the alarm from operating, and lets the user over-sleep. This tightly-coupled configuration requires additional complexity in the base station to support additional independent wrist bands, hence Berman's stated intent to wake the second sleeper via the audio alarm. It also requires the wrist-band electronics to be active all the time, listening for an alarm signal, driving battery consumption.

The same basic problem plagues U.S. patent 5,894,455 to Sikes (1999). Here, the wristband is replaced with an ear-piece, and vibration with an audible alarm. Since the sound is emitted directly into the ear, it can easily be loud enough to wake the sleeper without waking anyone else. But, this approach has the same flaws as Berman's, in that it is totally reliant upon the base station. Also, the electronics must continually listen for an alarm signal, wasting battery power.

U.S. patent 4,456,387 to Igarashi (1984) avoids these problems by using an autonomous vibrating watch. However, those of us who have nearly jumped out of our skins when a vibrating pager "went off" would not consider this a pleasant way to awake. A rude awaking can degrade both attitude and productivity for the entire day.

U.S. patent 4,821,247 to Grooms (1989) bypasses virtually all of these problems with an in-ear alarm clock. But, this approach creates new problems.

Since the device is entirely self-contained, it has buttons and a display for setting the time and alarm functions. This simultaneously makes the controls too small for convenient use, and makes the ear-piece far too large for comfortable wear during sleep. It is large enough to be quite uncomfortable, and to be easily brushed from the ear during sleep. Older users, in particular, would still have to find their reading glasses to set the alarm.

BRIEF SUMMARY OF THE INVENTION

In accordance with the present invention, an ear-plug alarm comprises a base station, a separate device or personal computer software with interface, which sets the time, and any number of ear-pieces which provide autonomous timing and alarm functions after they are disconnected from the base station.

Objects and Advantages

The present invention overcomes deficiencies in the prior as follows:

(a) An alarm which rests securely in the sleeper's ear will not be pushed aside during sleep, and the sleeper cannot roll away from it, like an alarm pillow, so that the sleeper will be awakened reliably.

(b) An audio alarm wakes the sleeper to a comfortable and familiar sensation, unlike vibrators. Indeed, the goal is to reliably awaken the sleeper while "alarming" her as little as possible.

(c) A pleasant chirp sound with a low repetition rate (about 1 Hz) provides a reliable but mild awakening. The changing tone is more effective than a static tone, and the chirp crosses a wide range of frequencies, mitigating the impact of any partial hearing loss.

(d) Generating the alarm in a programmable processor allows considerable flexibility in controlling volume, tone, or in producing specific sounds. This functionality is well established in the prior art, and could easily be added to the current embodiment.

(e) Placing the alarm directly in the ear provides substantial volume levels to the sleeper, which are, nonetheless, imperceptible only a few feet away. Releasing the sound directly into the ear canal, as opposed to near the ear in an earring configuration, magnifies this effect, and further damps any escaping sound.

(f) The in-ear configuration also damps outside noise, providing an additional aid to sleep, without the liability of masking sounds from an external alarm clock. This solves the traditional dilemma of wanting to wear ear plugs for a noisy environment when you still need to get up in the morning.

(g) Making the ear-piece entirely autonomous after it is set removes any wires, preventing the ear-piece from being pulled out during sleep and removing the attendant safety hazard. It also removes the conductive path to the sleeper's ear, which is quite beneficial in areas prone to lightning strikes.

(h) Using a separate base station to set the alarm allows the ear-piece to be remarkably small. It does not need the additional size for buttons or a display. With production electronics it could easily be manufactured to sit entirely within the ear canal, essentially immune to being dislodged during sleep. Even the current embodiment for low-quantity production using commercially available components, is far smaller than previous inventions that required the ear-piece to be fully autonomous.

(i) Setting the ear-piece from the base station greatly relieves accuracy requirements for the ear-piece timing system. The ear-piece is not required to maintain an accurate time-of-day over months, only to count the time until alarm for a single sleep. This allows the current embodiment for low-quantity production to be built without adding a timing crystal, while still maintaining accuracy to a few minutes.

(j) Use of commercially available gel ear adapters allows a simple ear-piece built from commercially available parts to rest comfortably and to remain reliably in the ear. Different adapters handle different sized and shaped ears.

(k) Non-volatile time storage in the ear-piece and autonomous operation after disconnect allows a single base-station to support an arbitrary number of ear-pieces. Each ear-piece remembers its previous setting, so that it can simply be turned on for the next day.

(l) Autonomous operation after disconnect makes the alarm immune to house power failures.

BRIEF DESCRIPTION OF DRAWINGS

In the drawings, closely related figures have the same number but different alphabetic suffixes. The same guideline is followed for reference numerals.

Figs 1A and 1B show the separate components of the ear-plug alarm. In 1B the base station is implemented using a personal computer and interface, as in the current reduction to practice.

Fig 2 shows the function blocks of the ear-piece.

Fig 3 shows the embodiment of the ear-piece and of the personal computer interface.

Fig 4 shows the sequence of events in the personal computer software or base station logic for retrieving the setting from an ear-piece, and for applying new settings.

Fig 5 shows the time multiplexed protocol used for bi-directional communication between the ear-piece and the base station over a single wire.

Fig 6 shows the time wave form for the RS-232 sync character used in this communications protocol, an ASCII control-H.

Fig 7A shows the format of current-time messages from the ear-piece to the base station.

Fig 7B shows the format of new setting messages from the base station to the ear-piece.

Fig 8A shows the object code for the current embodiment of the ear-piece, using an Atmel ATTiny12 micro-controller.

Fig 8B shows the object code for the micro-controller in the current embodiment of the personal computer interface.

Fig 9 shows the assembled configuration for the ear-piece.

Reference numerals in drawings

10	ear-piece
11	ear-piece connector
15	gel ear-piece adapter
16	interface adapter
17	base station connector
18	personal computer
19	base station
20	ear-piece interface
21	disconnect and power
22	signal separation
23	ear-piece battery
24	controller
25	timer
26	non-volatile storage
27	sounder
30	micro-jack
31	stereo micro-plug
33	RS-232 level converter

34	interface processor
35	ear-piece processor
36	ear-piece isolation capacitor
37	interface isolation capacitor
39	RS-232 data lines in/out
41	repeat test
42A	transmit wait
42B	second transmit wait
43	send sync
44	receive setting
45	setting available test
46	setting match test
47	calculate delay
48	send new setting
51	base station transmit interval
52	transmit idle interval
53	receive interval
54	base station transmit OK interval
55	ear-piece transmit interval
56	ear-piece transmit wait delay
57	ear-piece setting wait delay
58	minimum transmit idle delay
59	base station transmit delay
60	sync signal wave form

61	bit-time reference marks
65a	first low pulse
65b	second low pulse
66	transmit line idle
67	start bit
68	data bits
69	stop bit
71	start message flag
72	setting least-significant byte
73	setting most-significant byte
74	ear-piece data byte-1
75	ear-piece data byte-2
76	end message flag
77	delay byte-1
78	delay byte-2
79	delay byte-3
90A	battery - contact
90B	battery + contact
91	connection to case
92	conductive epoxy bond
93	sounder connection
94	contact to chip Vcc
95A	insulating layer
95B	second insulating layer

96A wire routing hole

96B wires to connector

97 cored-out piezo microphone

98 plastic cap

99 gap

DETAILED DESCRIPTION

Overview (Fig 1)

The preferred embodiment of the ear plug alarm is presented in Fig 1A. An ear-piece **10** connects to a base station **19** for setting the alarm, then operates autonomously when disconnected. In Fig 1B the base station **19** is implemented using software on a personal computer **18** with an interface adapter **16** to adapt RS-232 serial signals to the ear-piece **10**. The ear-plug alarm would be available in both configurations. A base station connector **17** is placed into an ear-piece connector **11** to set the time, then removed afterward.

Rather than requiring that the ear-piece **10** be manufactured in a shape to fit the ear, it is placed in a commercially available gel ear-piece adapter **15**. These are available in different sizes, keeping the ear-piece **10** in place comfortably and reliably for sleeper with different ear sizes and shapes.

While the ear-piece **10** is connected to the base station **19** it is powered from the base station **19**. When disconnected it is powered by internal batteries, and operates autonomously.

Ear-piece functional elements (Fig 2)

The functional elements of the ear-piece **10** are depicted in Fig 2. An ear-piece interface **20** supports connection of power and signal from the ear-piece **10** to the base station **19**. A disconnect and power **21** circuit allows the

ear-piece **10** to be powered from the base station **19** while attached to it, and from a ear-piece battery **23** when disconnected. A signal separation **22** separates the setting signals from the power to the rest of the ear-piece **10**. A controller **24** handles all interface and control functions of the ear-piece **10**. It retrieves previous setting from a non-volatile storage **26** and reports them to the base station **19**. It receives settings from the base station **19**, stores them in the non-volatile storage **26**, and if the setting is "on", configures a timer **25** to implement the appropriate delay. After this delay has expired, an alarm tone is produced via a sounder **27**.

Data transmission protocols (Figs 5, 6, 7A, 7B)

To minimize connectors, receive and transmit for the ear-piece **10** is done on a single wire, using a half-duplex protocol described in Fig 5. The base station **19** is the master, and controls all communications to avoid collisions. We always start in a base station transmit interval **51**.

The first signal from the base station **19** is always a series of sync characters. As depicted in Fig 6, the sync character is an ASCII control-H, producing the sync signal wave form **60**. This is convenient for identifying bit timing because all negative-going pulses, first low pulse **65A** and second low pulse **65B**, are exactly 4 bits long, referencing to a bit-time reference marks **61**. As usual, RS-232 characters are sent least-significant bit first with one start bit **67** and one (or more) stop bit **69**, and with transmit line idle **66** in between. Note that the first low pulse **65A** actually extends beyond the data bits **68**, including the start bit **67**. The base station **19** sends 1/3 second of sync characters, 400 characters at the current rate of 1200 baud. The bit time is measured as 1/4 the duration of the low going pulses, and subsequent time outs are in bit times, simplifying the personal computer **18** interface. This also determines this bit time for returned messages. This approach makes it unnecessary for the ear-piece processor **35** or interface processor **34** in Fig 3

to know the personal computer **18** bit timing a-priori. The string of sync characters also allows the ear-piece processor **35** to identify the start of a new transmission.

The relatively long period of sync characters provides the ear-piece **10** time to awaken from low-power modes. While it is counting down a time event, a low power idle mode is used, where almost nothing operates but the timer. After the alarm has sounded the ear-piece **10** enters a power-off mode, to be awakened by subsequent communications.

Returning to Fig 5, the base station **19** initially transmits whenever it is ready. The period of active bit transitions defines the base station transmit interval **51**. After a minimum transmit idle delay **58** of 40 bits from the last transition, the base station **19** locks out further transmits. This time-out period defines the transmit idle interval **52**. The base station **19** is not permitted to transmit again until after the receive interval **53**, in the next base station transmit OK interval **54**. The actual base station **19** timing is defined by an additional base station transmit delay **59** of 160 bits after the end of the transmit idle interval **52**. During the receive interval **53** interval the base station **19** listens for data from the ear-piece **10**.

The ear-piece **10** uses this same timing, first listening for transmissions from the base station **19**, then waiting for an ear-piece transmit wait delay **56** of 50 bits before sending data. This is slightly longer than the minimum transmit idle delay **58** to avoid collisions on the data line. It must complete its transmission before the base station transmit OK interval **54**.

The format of the returned data is given in Fig 7A. The message starts with a start message flag **71**, an ASCII "S", and ends with an end message flag **76**, an ASCII "E". A setting least-significant byte **72** and setting most-significant byte **73** echo the most recent setting from the base station **19**, with

one exception. If the previous alarm time has been reached, the least-significant bit of setting least-significant byte **72** will always be zero.

The ear-piece data byte-1 **74** and ear-piece data byte-2 **75** are not explicitly used. They were included in the message for diagnostic purposes. They give the timer control register setting and the divide down reset count for the ear-piece processor **35**, respectively. The values are described in the Atmel processor documentation.

Fig 5 shows as much of the protocol as must be understood by the interface processor **34**. It copies bits from the personal computer **18** to the ear-piece **10** during the base station transmit interval **51**, and copies bits in the other direction during the receive interval **53**. In parallel with the ear-piece processor **35**, the interface processor **34** decodes bit times from the sync signals in order to determine the appropriate delays. Since it is running off external power, it is never concerned with applying sleep or power down modes to reduce power.

After transmitting data during the ear-piece transmit interval **55**, the ear-piece **10** waits for at least an ear-piece setting wait delay **57** of 256 bits before returning to a power down state. This delay must extend beyond the end of the base station transmit delay **59** in the base station **19**, to assure that new setting data is received.

The format for new settings is given in Fig 7B. The start message flag **71**, end message flag **76**, setting least-significant byte **72**, and setting most-significant byte **73** are the same as in the previous settings message. The setting least-significant byte 72 and setting most-significant byte **73** combine to form a 16-bit setting value. But, only the least significant bit of this value has any meaning to the ear-piece **10**. It is a bit flag, 1 indicating that the ear-piece **10** is "on" and 0 indicating that it is "off". As with a typical alarm clock, this allows the time setting to be kept at a regularly-used value even when the alarm is not set. If the alarm is "off" the ear-piece **10** goes to

sleep and awaits further input after communications are completed. If the bit is "on" it goes into a count down and alarm sequence.

The other setting bits are used only within the base station **19**. The next bit, bit 1, indicates to the base station **19** whether the current setting is an absolute alarm time, 0, or whether it is a countdown delay alarm, 1. In the former case, the remaining bits give the number of minutes from midnight until the alarm time. In the later case these bits give the number of seconds of delay.

The actual timing information to the ear-piece **10** is contained in the next 3 bytes, delay byte-1 **77**, delay byte-2 **78**, and delay byte-3 **79**. These form a 24 bit word contain a delay count in "ticks" where one tick is 1024 millionths of a second. This delay specifies the time from the ear-piece **10** being set until the alarm should sound. Since the ear-piece **10** is always connected to the base station **19** when set, there is no need for the ear-piece **10** to keep an absolute time reference. These bytes have no particular meaning if the alarm is set to "off".

Base station logical flow (Fig 4)

The base-station logic for this process is given in Fig 4, as currently implemented in the personal computer **18** base station **19**. This sequence is used whenever the user indicates a desire to set the attached ear-piece **10**. Additional elements required in the software, such as a current-time display, setting controls, etc., are easily assembled by one skilled in the art, and the details of this implementation have no bearing upon the current invention.

If this is the first time that the base station **19** is communicating to the ear-piece **10** since the software has been initiated, a repeat test **41** bypasses the next step. Otherwise a transmit wait **42A**, as above, is applied to delay transmission into the base station transmit OK interval **54**. Having assured that the shared line is clear, the base station **19** does a send sync **43**,

using the sync described above. If the ear-piece **10** has already been awakened by reading its setting, a short, 8 character sync, can be used. It then listens for data from the ear-piece **10** in receive setting **44**. When simply reading the previous setting, as determined by setting available test **45**, this is the end of the process. When the user has supplied a new setting we first apply a setting available test **46**. If not, we return with an error. This verifies that the same ear-piece **10** is still in place. Breaking the process into two pieces in this manner allows the user to examine the current "set" time at leisure before specifying a new setting. Given now that we know this is the right ear piece and have a new setting, we go to the calculate delay **47** step. This converts the difference between the set time and the current time from the base station **19** into a time difference in "ticks" as above. Any possible delay up to 24 hours fits within the 24-bit tick count. Again, we wait until the next transmit window next transmit wait **42B**, and do the send new setting **48**.

This structure has some additional implications for the base station **19** logic. It can interrupt the current count down in the ear-piece **10** by sending a new sync. This is treated no differently than above. However, since the ear-piece **10** operates on a set delta-time, and this countdown is disrupted by a new setting, the base station **19** must supply a new delay. By default the ear-piece **10** will turn itself off when the current setting is read. The current base station **19** software leaves the alarm turned off if it was set for a time delay. If it was set for a specific alarm time and no new setting is supplied, a default setting corresponding to the same alarm time is sent to the ear-piece **10**.

Hardware implementation details (Figs 3, 8A, 8B)

The preferred embodiment given here is tailored for small quantity production, using off-the-shelf parts to minimize the initial investment,

albeit with methods not suited to quantity production. Implementing these functions in custom components for quantity production is a simple exercise for one skilled in the arts of miniature electronics and production packaging, given the interface and functional description presented. However, the method of producing a miniature ear-piece **10** from off-the-shelf components is far from obvious, and therefore is detailed here.

Fig 3 details the preferred embodiment of 1B. The base station connector **17** is implemented as a stereo micro-plug **31**. This form is used because it is widely available with receiving sockets, micro-jack **30**, which can disconnect ear-piece power whenever the plug is inserted. Ground is placed in the tip to avoid shorting power to the signal line as the plug is inserted. +V is on the plug base so that a full circuit is never completed until the plug is fully inserted. This leaves the signal line on the middle connector. Thus the micro-jack **30** serves the purposes of the ear-piece interface **20**, disconnect and power **21**, and signal separation **22** in Fig 2.

The left side of Fig 3 shows the interface adapter **16** which provides power to the ear-piece **10** and which multiplexes RS-232 serial port transmit and receive data from the personal computer **18** onto the single data line to the ear-piece **10**. It implements these function in an Atmel ATTiny12 micro-controller, an interface processor **34**, to make use of readily available commercial parts. Code for this processor is given in Fig 8B. Using the Atmel processor requires converting the RS-232 data lines in/out **39** to/from TTL in an RS-232 level converter **33**. This function is easily implemented in a variety of commercial parts. As per normal practice, the RS-232 connector to the personal computer **18** connects DTR to DSR and CTS to RTS, as defined in the RS-232 specification, to allow communication.

Power for the interface adapter **16** would typically come from a separate regulated power supply. In some cases, the power may be drawn from the computer's RS-232 DTR and regulated to the desired levels, but the current

implementation sometimes draws more current than some computers will supply. This would not be the case with custom electronic components. An interface isolation capacitor **37** has proven necessary across the power and ground for reliable operation in current configurations. The voltage should be the same as that from the ear-piece battery **23**, currently 3v.

The right side of Fig 3 shows the ear-piece **10**. As previously stated, the ear-piece interface **20**, disconnect and power **21**, and signal separation **22** are all provided by the micro-jack **30**. Specifically, the part used in a Stack Electronics SMT 2534. The controller **24**, timer **25**, and non-volatile storage **26**, are provided by an ear-piece processor **35**, another Atmel ATTiny12 micro controller. A lower voltage, Atmel "V", version is preferred to allow operation using a single battery, but this chip was not available for the initial prototype. The surface-mount packaging for ear-piece processor **35** is used here. The code for this micro-controller is given in Fig 8A. Again, an ear-piece isolation capacitor **36** has proven necessary for reliable operation with current parts.

To improve the timing accuracy the ear-piece **10** must be calibrated. The Tiny12 processor provides a timing calibration byte, as described in the Atmel documentation. This is loaded from byte 8 of the program memory. This must be replaced with a value that provides a 1MHz clock at the desired supply voltage when operating at body temperature. This can be measured before the unit is assembled with standard techniques. Proximity to the ear holds the unit at near body temperature, reducing thermal timing variations. Note that calibration is not necessary for the interface processor **34**, since it measures only relative timing.

The sounder **27** is a modified piezo-microphone. These microphones are readily available in standard condenser-microphone packages, about 1/4" long and in diameter, with a metal shell, and are constructed as follows: the shell edges are crimped over a small circuit card across the back with solder pads

for the signal leads. These microphones rely on the pressure fit of the crimped back, through the circuit card, through a plastic spacer, to an insulating gasket and metal holding disk, and finally to the piezo element and back to the case, in order to maintain an electrical connection. One pole of the piezo element is connected to the case. The other pole is connected, via the metal plate, to the base of a transistor inside the microphone. One transistor lead connects to the case. The case and the remaining transistor lead connect to solder pads on the miniature circuit card at the back of the microphone. These are the device terminals. We take advantage of this structure to form a uniquely compact device, by converting it into a sounder.

Assembly (Fig 9)

The piezo-microphone forms not only the sounder **27**, but also the case for the entire ear-piece **10**. Most of the other components are assembled inside this shell. This is strictly a concession to building this device in a small form-factor from commercially available parts. For a quantity production design with custom-manufactured parts, the following assembly details would not be germane.

First, we grind out the inside of the piezo microphone, being sure to leave the plastic spacer material under the crimped edges intact, as required to maintain the pressure connection to the piezo element. This can easily be done with a small grinding element on a Dremel tool. The plastic cannot simply be drilled out. A drill of the appropriate diameter puts too much torque of the plastic spacer, causing it to spin and ruining the piezo element. After most of the material has been removed, the transistor is exposed. It remains connected only to the metal plate over the piezo element: the other two connections have been ground off. The transistor is broken free with dental tools. Sometimes the lead remains attached to the metal plate, and can be ground off. This leaves us with the cored-out piezo microphone **97** in Fig 9.

Next, we attach a short wire to the metal plate, the sounder connection **93** using a conductive epoxy bond **92**. This produces a sounder sub-assembly.

The ear-piece processor **35** will be inserted inside the cored-out piezo microphone **97**, but first everything must be attached to it. A surface-mount package is used, DIPS do not fit in the space available.

After the chip is programmed, the DB4 pin is bent backward until it is flat against the top of the chip. DB pins are defined in the Atmel documentation. The other end of sounder connection **93** is soldered to this pin. Note that the chip will be installed upside down. Of the remaining pins, only power, ground, and DB2 are used. These are bent flat against the sides of the chip in the other direction, and clipped flush with the bottom. Wires are soldered to these pins before proceeding. The remaining pins are clipped off. These wires will be connected as shown in Fig 3: fig 9 does not show every connection.

Next an insulating layer **95A** is glued to the bottom of the chip, to prevent pins from shorting against the battery contacts which will be placed next. Power transistor base pads can be cut down and serve well for this purpose. A battery - contact **90A**, second insulating layer **95B**, and battery + contact **90B** are glued in order on top of this as shown. Battery contacts are sized and bent to firmly hold the ear-piece battery **23** between them. In practice, two batteries are used in series. Note that the battery + contact **90B** is connected both to the wires to connector **96B** and to the contact to chip Vcc **94**. The ear-piece isolation capacitor **36** is placed across the chip power and ground using a short insulated wire. All of these components are attached so that they do not extend beyond the footprint of the ear-piece processor **35**.

This subassembly is pushed down inside the cored-out piezo microphone **97**, with wires to connector **96B** routed out through a wire routing hole **96A**. After it is in place a connection to case **91** connects the battery - contact **90A** to the remnants of the cored-out piezo microphone **97** case-connection solder pad.

This provides the return circuit for the piezo sounder. A small non-conductive ribbon is then glued to the edge of the cavity so that the ribbon goes into the cavity, then back up the other side. This is the usual aid to help remove batteries. At this point we have a cored-out piezo microphone **97** with wires to connector **96B** extending from it.

The micro-jack **30** is first prepared by folding the surface mount leads back against the under side of the part. The wires to connector **96B** are cut as short as practical and soldered to the micro-jack **30**, which is then epoxied to the outside of the case, contacts inward. Epoxy is placed over the wires and contacts to protect them, and to insulate contacts from the case. The micro-jack **30** must be placed so that it does not extend to the back of the case, so that socket is nominally horizontal, into or out of the paper, and so that the plug may be inserted while the ear-piece **10** is inside the gel ear-piece adapter **15**. Detailed connections to the micro-jack **30** are given in Fig 4, and are not reproduced here.

Batteries are placed inside the remaining opening, and a plastic cap **98** keeps them free from contamination. The plastic cap **98** must be cut to length, and must have a gap **99** cut in one side to fit over the expoxied micro-jack **30**. Note that it may stick somewhat above the base station connector **17**, depending upon the batteries selected. Suitable caps are available from Caplugs. The type used to protect cable-TV splitter sockets also works well.

Alternative embodiments

Nothing in this description should be construed as restricting the implementation to that described. For example, the following are obvious extensions:

(a) The entire assembly could be replaced with custom components, eliminating the current assembly procedure.

(b) The specific micro-controllers can be replaced with other chips.

(c) The micro-jack **30** and stereo micro-plug **31** could be replaced with other type of connectors, particularly favoring those without open orifices. Inductive coupling is a particularly desirable option.

(d) The RS-232 connection to the interface adapter **16** can be replaced with other standard personal computer **18** interfaces, such as USB. The protocol would, of course, have to be modified appropriately.

(e) The need for the gel ear-piece adapter **15** can be eliminated by using an appropriately shaped case with soft elements. To support a variety of users, adapting components would still be required.

(f) The disposable ear-piece battery **23** could be replaced with a rechargeable battery and charging mechanism.

(g) Volume control and sound selection mechanism can easily be added. The methods are simple to one versed in the art.

(h) The ear-piece **10** could process an absolute alarm time, rather than a time delay after it is set. This might be simpler if more extensive clock functions are added to the ear piece (sharp time, etc.), but would require a method to set and verify the internal clock.

Conclusions, ramifications, and scope:

By separating the alarm clock into a base station and autonomous ear-piece we obtain a wide variety of advantages.

(a) The ear piece becomes far smaller and more usable, particularly by virtue of eliminating displays and controls. This is such an overwhelming benefit that it makes it possible to construct a usable-sized ear-piece from off-the-shelf components. Even with productization and custom parts for quantity production, this is a substantial benefit.

(b) This approach eliminates dangerous wires, and removes any dependency upon the base station after the ear-piece is disconnected from it.

(c) The base station becomes able to support an unlimited number of ear-pieces, without any added complexity. Each ear-piece remembers its own settings, so that it may be simply turned "on" again for the next night.

(d) The ear-piece can simply count down from the time at which it is set, thus it has no need to maintain absolute accuracy over an extended time. A simple timing mechanism is sufficient.